TITLE

ELECTROMECHANICAL CYLINDER PLUG

CLAIM FOR PRIORITY

This application makes reference to, incorporated the same herein, and claims all benefits accruing under 35 U.S.C. §§119 and 120 from provisional applications entitled *Electromechanical Cylinder Plug* earlier filed in the United States Patent & Trademark Office on the 29th of September 1995 and duly assigned Serial No. 60/004,594, and filed in the United States Patent & Trademark Office on the 12th of February 1996 and duly assigned Serial No. 60/011,764.

FIELD OF THE INVENTION

This invention relates to access security systems generally, and more particularly, to electromechanical locks and to the plugs and cylinders of electromechanical locks.

BACKGROUND ART

In an effort to both control and monitor access, state-of-the-art contemporary access security systems have begun to electrically couple the hardware of individual locks to a central, or host, computer. This enables the systems at a minimum, to monitor the operation of each lock and more commonly, to additionally control access to the space guarded by each lock by the expedient of

controlling, or at least regulating operation of individual locks. Although some systems rely simply either wholly, or partially, upon recognition of a code borne by a pass, or credential, that contains a memory (*e.g.*, a magnetic strip or embedded memory chip) bearing a code unique to the pass, more elaborate systems such as the *ELECTRONIC SECURITY SYSTEM* of R. G. Hyatt, Jr., *et al.* disclosed in U.S. Pat. No. 5,140,317 issued on 18 August 1992, use both an electronic lock mechanism and an electronic key, both of which are provided with a microprocessor and a memory storing an identification code. More recent efforts such as the *DUAL CONTROL MODE LOCK* of T. J. DiVito, *et al.*, U.S. Pat. No. 5,423,198 issued on 13 June 1995, endeavors to further enhance access security by first having the blade of a key bearing the correct profile and bitting transmit an enable signal upon insertion into the keyway of a particular rekeyable locking mechanism, and then having a second coded signal electromagnetically displace one or more pin tumbler stacks to enable rotation of the plug relative to the cylinder.

It has been my observation that these access security systems tend to require complete replacement of each previously installed locking mechanism. I have found that this is not always feasible because some locks have a cylinder formed as an integral part of the secured item (*e.g.* a hospital drug cart), while other items and areas lack sufficient space to accommodate replacement of an existing mechanical lock with the larger volume of a contemporary electromechanical lock. Moreover, contemporary electromechanical lock systems typically require that each lock be electrically wired into a network with either a source of power or a data or control bus. While this is possible with many architectural applications and with secured items such as a coin box of a pay telephone, in other situations I have found that either the remote location of the lock, the difficulty

in stringing the necessary wiring, or customs in the particular industry concerning placement of a lock on the secured item, or area, make the installation of an electromechanical lock that is wired into a network impractical.

I have also noticed that both the expense of the complete replacement of each locking mechanism and the expense of the replacement electromechanical locking system have limited the market for such systems to users where either enhanced security is paramount (*e.g.*, hospital drug cabinets) or excess system costs are not a disadvantage because the user (*e.g.*, a regulated utility such as a telephone company that installs electromechanical locks on the coin boxes of its pay telephones) is able to claim an annual return based upon the cost of savings generated by the system. I have discovered that although both classes of users would be able to attain the same level of security from less elaborate systems, the willingness of such users to readily bear these costs as well as the ages old illusion of security concomitant with expense, has hidden the possibility of improving upon current access security systems.

Moreover, I have found that despite their innate complexity, many contemporary electromechanical lock systems are able to provide only a single level of access security; thus the cost of equipping each user to use a particular lock remains the same - each user must have the same expensive battery powered microprocessor controlled key, despite the fact that different users of that lock may have different levels of access via that lock. Loss or damage of the microprocessor controlled key can not, in my observation, be minimized by the owner of the lock. Furthermore, electromechanical locking systems tend, because of their excessively elaborate designs, to be unique to their manufacturers. Accordingly, users become captive to their initially selected manufacturer.

Consequently, other potential classes of users subject to considerations of costs for replacement of existing locks, costs of the replacement systems as well as costs of operation of the replacement and costs of periodic repair and maintenance, have been denied the benefits of less expensive electromechanical locking systems able to provide the same level of access security, despite the fact that security is also a paramount concern of such users (*e.g.* a prison or other governmentally funded institution).

SUMMARY OF THE INVENTION

It is therefore, one object to the present invention to provide a more sophisticated electromechanical locking mechanism.

It is another object to provide a plug suitable to readily convert an existing locking mechanism into an electromechanical locking mechanism.

It is still another object to provide a replacement plug able to incorporate an locking mechanism into an electromechanical locking system.

It is yet another object to provide an electromechanical locking system able to accommodate a hierarchy of access security requirements.

It is still yet another object to provide lock components enabling retrofitting of an existing locking mechanism with an electromechanical locking mechanism, without requiring replacement of all of the components of the existing locking mechanism.

It is a further object to provide lock components enabling conversion of an existing locking mechanism into an electromechanical locking system, by replacing less than all of the components of

the existing locking mechanism.

It is a still further object to provide an electromechanical plug that, with a minor alteration of a lock's cylinder, enables the lock to be incorporated into an electromechanical locking system.

It is a yet further object to provide an electromechanical lock able to be set to a plurality of operationally locked, unlocked, and partially bypassed conditions.

It is a still yet further object to provide an electromechanical plug that enables each lock to be individually set, either locally or remotely, to grant access to a secured item or area in response to any one of a plurality of keys providing a plurality of different keys levels of operational access.

It is also an object to provide an electromechanical locking mechanism having its electronic circuits and all of its electromechanical actuating elements incorporated wholly into the body of a plug.

It is an additional object to provide an electromechanical locking mechanism that is amenable for use both as one lock within an electrical network of electromechanical locks and alone independently of any host electrical power or control network.

It is a still additional object to provide a drop-in substitute plug able to convert contemporary cylindrical locks into electromechanical locks able to provide a plurality of different levels of access security.

These and other objects may be achieved with a hierarchically adaptable lock using a removable cylindrical plug rotatably held with a lock cylinder of a locking mechanism. The plug has an exposed terminal face base perforated by a keyway and a distinct electrical contact aperture. The plug contains either a mechanical locking mechanism, such as a rekeyable tumbler stack, and an

electrical operator, or simply a key retaining mechanism and an electrical operator, wholly within the cylindrical exterior surface of the plug. The opposite base of the plug operationally supports a tailpiece able to rotate a cam and position a bolt of the locking mechanism. After insertion of a blade of a properly bitted and profiled key, electrical power, or alternatively electrical power and a data signal superimposed upon the electrical power, may be transmitted from electrical circuits of the key to the electrical operator within the plug. Activation of the electrical operator within the plug, in conjuction with correct displacement of the mechanical locking mechanism, or in the embodiments constructed without a mechanical locking mechanism, simply activation of the electrical operator, enables rotation of the plug within the cylinder as torque is manually applied to the blade of the key. An electronic memory, or an electronic memory and an electronic logic circuit wholly contained within the plug, may be electrically interposed between the electrical operator and the electrical contacts receiving power, or power and data signals, from the key.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of this invention, and many of the attendant advantages thereof, will be readily apparent as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference symbols indicate the same or similar components, wherein:

Figure 1 is an exploded perspective view showing the details of a structure able to support several alternative embodiments of a lock constructed according the to principles of the present invention;

Figure 2 is a top detailed view of an electrical operator of a type suitable for use in the embodiments shown in Figure 1;

Figure 3 is an enlarged cross-sectional detail view showing the structure of a first embodiment of a lock constructed according the to principles of the present invention;

Figure 4 is a top detailed view of one armature of an electrical operator of a type suitable for use in the embodiments shown in Figure 1;

Figures 5A and 5B are two enlarged cross-sectional detailed views showing two different operational positions of the structure of a second embodiment of a lock constructed according to the principles of the present invention;

Figure 5C is a side cross-sectional view of another embodiment, showing one phase of the operation of the lock;

Figure 5D is a side cross-sectional view of the embodiment illustrated in Figure 5C, showing another phase of the operation of the lock;

Figure 5E is a side cross-sectional view of one design for a motor suitable for use in the embodiments shown in Figures 5A, 5B, 5C and 5D;

Figure 5F is a plan cross-sectional view taken along sectional line VF-VF' in Figure 5E, of one detail of the motor shown in Figure 5C;

Figure 6 is a top detailed view of an armature for another electrical operator of a type suitable for use in the embodiment shown in Figure 1;

Figure 7 is an enlarged cross-sectional detailed view showing the structure of the embodiment incorporating the armature illustrated in Figure 6;

Figure 8A is an exploded perspective view of another alternative embodiment constructed according to the principles of the present invention;

Figure 8B is an upper plan view of the embodiment illustrated in Figure 8A;

Figure 8C is a front elevational view of the embodiment illustrated in Figure 8A;

Figure 8D is a side elevational view of the embodiment illustrated in Figure 8A;

Figure 8E is a rear elevational view of the embodiment illustrated in Figure 8A;

Figure 8F is a cross-sectional view of an electrical operator of a type suitable for use in the embodiment illustrated in Figure 8A;

Figure 8G is a cross-sectional view showing the assembly of the lock illustrated in Figure 8A;

Figure 8H is an exploded perspective view of another alternative embodiment constructed according to the principles of the present invention;

Figure 9 is an upper plan cross-sectional view illustrating some of the details of the embodiments of Figure 1;

Figure 10 is a front elevational view illustrating some of the details of the embodiments of Figure 1;

Figure 11 is a side cross-sectional elevational view illustrating some of the details of the embodiments of Figure 1;

Figure 12 is a rear elevational view illustrating some of the details of the embodiments of Figure 1;

Figure 13 is an enlarged cross-sectional detailed view showing the structure of an alternative embodiment constructed according to the principles of the present invention;

Figure 14 is an oblique perspective view of an assembled alternative embodiment constructed according to the principles of the present invention;

Figure 15 is a cross-sectional detailed view showing the structure of an alternative embodiment constructed according to the principles of the present invention;

Figure 16 is an oblique view showing details of a case for a logic circuit that may be incorporated into several of the embodiments of the present invention;

Figure 17 is an oblique view showing details of an alterative embodiment of a case for a logic circuit that may be incorporated into several of the embodiments of the present invention;

Figure 18 is a block diagram illustrating circuits for both a key and a lock, constructed according to the principles of the present invention;

Figure 19 is a diagrammatic view illustrating one configuration of a hierarchical lock cylinder system practiced according to the principles of the present invention;

Figure 20 is a diagrammatic view illustrating a second configuration of a hierarchical lock cylinder system practiced according to the principles of the present invention;

Figure 21 is a diagrammatic view illustrating a third configuration of a hierarchical lock cylinder system practiced according to the principles of the present invention; and

Figure 22 is a diagrammatic view illustrating one configuration of a hierarchical lock cylinder system practiced according to the principles of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Turning now to the drawings, Figure 1 provides an exploded perspective view of a cylindrical

camlock 100 of the type in general use for securing access to cabinet doors, drawers and coin boxes. The principles illustrated by camlock 100 are however, readily suitable for other types of locks. As shown in the various views of Figures 1 through 18, a camlock is assembled with an elongate, cylindrical plug 101 inserted inside the cylindrical cavity 102d of cylinder shell, or body, 102. Typically, lock 100 is constructed with end plate 68 at the terminal end of cylinder 102, recessed to receive face plate 72 of plug 101 so that the exposed surface of plug 101 lies flush with the face of plate 72. Absent such key retaining components (*i.e.*, those components of the plug that retain the shank of a key (*e.g.*, such as bitted key 200) within the keyway while the plug is rotated from its rest position relative to the shell 102) of the locking mechanism as cylindrical pins 101b and sidebar 101g, plug 101 should be sized to freely rotate around an axis that is parallel to the longitudinal axis of cavity 102d. Plug 101 contains an axially elongated keyway passage 101a shown in the front, cross-sectional and rear views of Figures 10, 11 and 12, respectively, extending axially through the exposed front plate 72 of cylindrical plug 101. Keyway passage 101a is configured to accommodate reciprocal insertion of the blade of a key 200 that has been correctly profiled to conform to the profile of keyway 101a. Although not essential to the practice of all embodiments of the principles of this invention, plug 101 may also contain a mechanical locking mechanism such as a set of pin tumblers 101b of the type mentioned in U.S. Patent Nos. 3,722,240 and 3,499,303 to Oliver. Pin tumblers 101b are biased by springs 101e into the bottom of corresponding pin chambers 82 by corresponding separate springs 101e restrained within the body of plug 101 by coverplate 101f fitted snugly into an axially extending slot 101y adjacent to the exterior circumferential surface of plug 101.

Plug 101 also contains sidebar 101g tapered into an acute (frequently blunted), axially

extending bearing edge 101h partially recessed into a slot 102a formed axially along the exterior circumferential surface of cylinder 102. Sidebar 101g is typically biased radially outwardly by one or more springs 101k so that the leading axially extending edge 101h of sidebar 101g protrudes into a beveled slot 102a of a cylinder 102 encasing plug 101 after the complete plug 101 has been installed into cylinder 102. Pins 101b are cut in this particular embodiment with a groove 101d. When the blade of a mechanical key that has been bitted to correctly displace pins 101b radially outwardly from keyway 101a within their corresponding chambers 82 is inserted with the cuts of the land of the key precisely matching the coding (axial separation between the upper and lower portions of pins 101b) of pins 101b, then slots 101d will align with the legs, or pegs, 101m of the sidebar 102g. When rotational torque is manually applied to the key by the user, the beveled edges of slot 102a enables sidebar 101g to move radially inwardly and away from groove 102a against the bias of springs 101k slightly, but enough to allow plug 101 to rotate within cylinder 102, thus concomitantly rotating tailpiece 101q which, in turn, rotates a movable cam 103 or other member engaged by tailpiece 101q. In other applications, cam 103 may be connected to and, upon rotation of plug 101 and its tailpiece 101q, draw a bolt and thereby permit access to a secured item or into a secured area. Other embodiments allow a tailpiece 101q with a particular shape to drive a clutch, cam or linkage.

The user may then rotate the key until plug 101 is aligned with a key extraction point where alignment between chambers 82 and the corresponding tumbler pins 101b allow the bias of springs 101k to force sidebar 101g radially outwardly until beveled edge 101h mates with slot 102a, and thus permits withdrawal of key 200 from keyway 101a. A cylinder lock of this type may have two or more grooves, or slots 102a spaced arcuately apart to provide several arcuately separate points at which

a key may be extracted from plug 101. When pins 101b are engaged in the properly manufactured corresponding cuts in the blade of the key and each of pins 101b is correspondingly radially displaced outwardly within its chamber, and legs, or pegs, 101m of sidebar 101g engage corresponding circular grooves 101d formed in some, or all, of pins 101b as those pins 101b are forced radially outward by the bits of the key. The interengagement of pegs 101m and grooves 101d prevents radial movement of pins 101b and the concomitant release of the blade of the key within keyway 101a; the blade may only be extracted from keyway 101a when beveled edge 101h of sidebar 101g is correctly aligned with groove 102a. It should be noted that features of mechanical lock and key mechanisms other than those mentioned in U.S. Patent Nos. 3,722,240 and 3,499,303 to Oliver may be used in the practice of the instant invention. ,

A release assembly such as a reciprocating solenoid coil 106b driving blocking armature 106a shown in greater detail in Figures 2 and 3, or a rotary motor 108b driving blocking armature, 108a shown in greater detail in Figures 4 and 5A and 5F, or the reciprocating solenoid coil 107b of blocking armature 107a shown in greater detail in Figures 6 and 7, resides within (typically cylindrical) chamber 80. The open distal end of chamber 80 is intersected by a circumferential groove 101ℓ which may partially, or completely, encircle the exterior circumferential surface of plug 101. Coil 106b has a centrally located hole 106f for receiving shaft 106d while detent 106A passes either sidewall 106e of blocking armature 106a. Armature 106a forms the radially outward distal end of solenoid coil 106b, and is radially outwardly biased by spring 106D so as to extend radially upwardly into the path of groove 101ℓ and thereby engage detent 106A. Release assemblies 106, 107, and 108 are electrically connected to an electronic logic and control circuit 104b encapsulated within an

electrically insulated casing 104 formed to define an outer sector of cylindrical plug 101. Power, or power, protocol, identification and control data may be transmitted from a key inserted into keyway 101a via electrical conductor 104x, extending between an aperture 101n in the face plate 72 of plug 101 and the electrical conductor (*e.g.*, a local ground return) formed by the electrically conducting parts forming keyway, respectively, and corresponding input ports to circuit 104b. Electrical leads 104m, 104n, extend between a pair of output ports of circuit 104b and either solenoid coil 106c of blocking armature 106a, or solenoid coil 107c of blocking armature 107a, or motor coils 108c of rotary stepping motor 108a.

The electrical power or alternatively, electrical power, operational protocol, identification and control data passes through aperture 101n via conductor 104x when casing 104 is properly positioned within cavity 101p. Pegs 101s enter corresponding receptacles in casing 104 and position casing 104 relative to plug 101. When casing 104, and its electronic circuit, are seated within plug cavity 101p, casing 104 is contained within the larger diameter of plug 101, so that the combined plug assembly formed by plug 101 and electronic circuit casing 104 are easily and tightly received within the interior of lock cylinder 102. Blocking armature 106a, 107a or 108a, may be rendered ineffective at limiting or preventing rotation of plug 101 within cylinder 102 and thus considered to be mechanically bypassed until the installation of a cooperating member clip 105E or 106E, respectively within slot 102c with the respective detent 106A, 107A disposed within through aperture 102b. A selected one of cooperating member clips 105E or 106E installs circumferentially around cylinder 102 and is seated within a conforming circumferential groove 102c when blocking detent 105A or 106A is engaged through slot 102b. When installed properly, blocking detent 105A or 106A extends

through slot 102b and sufficiently into the exposed recess 106c, or slot 107c, 108c in the distal end of the corresponding one of armatures 106a, 107a, 108a, and as plug 101 rotates within cylinder 102, blocking detent 105A, 106A travels through groove 101ℓ around the circumference of plug 101. The shafts 106d, 107d or 108d respectively of blocking armatures 106a, 107a or 108a are made of a magnetically attracted material such as iron or steel. When an unidirectional electrical current is applied through the particular winding 106b, 107b, 108b, the corresponding shaft 106d, 107d, 108d will either axially reciprocate (*i.e.*, radially through its corresponding chamber 82) along axis A or incrementally rotate (*e.g.*, by ninety degrees within its corresponding chamber 82) around axis A and thereby alter the positional relation between blocking detent 106A or 107A relative to the corresponding blocking armature 106a, 107a or 108a.

In the embodiment illustrated by Figures 2 and 3, cooperating member clip 106E and blocking armature 106a are used as a set to form electromechanical release mechanism 106. When clip 106E is inserted into groove 101ℓ with detent 106A protruding through slot 102b, compression spring 106D will hold armature 101a radially outwardly from the coaxial void 106f formed by coil 106b, so that cavity 106c will surround detent 106A. Consequently, sidewalls 106e will stand between detent 106A and circumferential groove 102ℓ, thereby blocking rotation of plug 101 within cylinder 102. Assuming that mechanical key cuts (*i.e.*, the "bitting" along the shank of a conventional mechanical key 200) correspond with the coding of mechanical pins 101b, insertion of a key (not shown) into keyway 101a and manual rotation of the key in any direction is blocked by obstruction of detent 106A by stopface 106e; application of power to coil 106b via contact 104x and controller 104, and a responsive reciprocally downward movement of the magnetically attracted blocking armature 106a

along axis A toward coil 106b enables the straight edge 106F of blocking detent 106A to clear the upper edge of stopface 106e and to pass freely in that direction within groove 101ℓ. When power is discontinued to coil 106b, spring 106D will then return blocking armature 106a to its extended position, thereby again blocking rotation of plug 101 in any direction due to obstruction of detent 106A by sidewall 106e. If detent 106A is within groove 101ℓ and is not axially aligned with cavity 106c when application of electrical power is withdrawn from coil 106b, continued manual rotation of the key will cause angular edge 107B of detent 106A to engage a slight chamber on the upper edge of armature 106a at 106h; camming action of edge 106B will force armature 106a to axially reciprocate inwardly within its chamber 80 until detent 107A is again engaged by the return outward reciprocating movement of armature 107a under the bias of spring 107D. When detent 106A is coaxially aligned with cavity 106c, springs 101k force edge 101h of sidebar 101g radially reciprocate outwardly from grooves 101d and into groove 102a, thereby enabling manual withdrawal of the key from keyway 101a.

Turning now particularly to Figures 4, 5A, 5B, 5C, 5D, 5E and 5F, when cooperating member clip 106E and blocking armature assembly 106a are used as a set to form release mechanism 108, clip 106E will rest within cavity 108c, defined by two mirror image and spaced apart sidewalls 108e in blocking armature 108a while plug 101 is in the locked position relative to cylinder 102 with edge 101h of sidebar 101g resting within groove 102a. Blocking armature 108a is coaxially mounted upon the shaft of a stepping motor 108A. As represented in Figures 5A, 5B, 5C and 5D, the stepping motor has a single coil 108b; the embodiment shown in Figures 5E and 5F use a pair of coaxial coils 108b. The entire motor assembly is encased in a can 108j that is in turn, fitted into cylindrical hole

80. Preferably, stepping motor 108A rotates by ninety degrees in response to application of electrical current to coil, or coils 108b. Referring now to Figure 5A, assuming that upon manual insertion of a key within keyway 101a, mechanical key cuts along the shank of the key correspond to coding of the row of mechanical pins 101b, rotation of the key in either direction is blocked by engagement of detent 106A with sidewalls 108e of cavity 108c in blocking armature 108a. Turning now to Figure 5B, application of power to solenoid coil 108b and an accompanying rotation of blocking armature 108a around axis A relative to coil 108b in response to flow of the current, enables the straight lowermost edge 106F of blocking detent 106A to pass through gap 108h between opposite sidewalls 108e of cavity 108c and to pass freely into groove 101ℓ, thereby enabling rotation of plug 101 within cylinder 102. When the key is withdrawn from keyway 101a, blocking armature 108a will remain in its current position, thereby blocking rotation of plug 101 in either direction if the current position is as shown in Figure 5A with sidewalls 108e interposed between groove 101ℓ and detent 106A. If however, the current position of blocking armature 108a is as shown in Figure 5B when the key is withdrawn, detent 106A will be able to freely rotate through gaps 108h and into groove 101ℓ when another key with the correct bitting is inserted into keyway 101a. If tab 106A and cavity 108g are significantly misaligned when power is discontinued, then rotation of the plug 101 to the key extraction point where mechanical key retaining pins 101b may disengage from the key blade due to the movement of sidebar 101g into groove 102a, will position small tapered edge 106B to encounter chamber 108g. As plug 101 is rotated farther, armature 108a is pushed into the void 108f coaxially defined by coil 107b until tab 106A is again engaged by the return outward movement of armature 108a. NMB Corporation currently manufactures a stepping motor, model number 03BJ-H001-F9

of a type that is sufficiently minaturized to serve in this embodiment. This model uses two separately wound coils 108b. Application of electrical current to the coils incrementally steps the armature 108a to align with the energizied ferrous fingers 108n mounted upon the casing and the ferrous fingers 108p mounted upon the ferrous divider 108q. An electrical insulator 108k is mounted on shaft 108d to serve as a divider. Reversal of electrical polarity to the coils will cause a reversal of the direction of rotation of armature 108a. Preferrably, each application of power to the coils will initiate a ninety degree rotation so that sidewall 108e will either block passage of detent 106A into groove 101ℓ, or the alignment of slot 108h with detent 106A will accommodate passage of detent 106A into groove 101ℓ and thus enable rotation of plug 101 within cylinder 102.

Turning briefly now to Figures 6 and 7, when cooperating member clip 107E and blocking armature 107a are used as a set to form release mechanism 107, detent 107A of clip 107E will engage stopface 107e on blocking armature 107a, if plug 101 is rotated in one direction. Assuming that the mechanical key cuts (*i.e.*, the "bitting" along the shank of a conventional mechanical key) correspond with the mechanical pin coding, rotation in one direction is blocked by stopface 107e and requires application of power to coil 107b and a responsive reciprocally downward movement of the magnetically attracted blocking armature 107a toward coil 107b so that the straight edge 107F of blocking detent 107A clears the upper edge of stopface 107e and passes freely in that direction within groove 101ℓ. When power is discontinued to coil 107b, then spring 107D will return blocking armature 107a to its extended position, thereby blocking rotation of plug 101 in one direction due to obstruction of stopface 107e by detent 107A, while plug 101 is free to rotate in the opposite direction through groove 101ℓ. If plug 101 is rotated in this opposite direction far enough, angular

edge 107B will engage a slight chamber on the upper edge of armature 107a at 107h; camming action of edge 107B forces armature 107a axially (radially within its chamber 80) inwardly until detent 107A is again engaged by the return outward movement of armature 107a under the bias of spring 107D.

Figures 8A through 8F illustrate the structure of two different drop-in modifications of a contemporary lock, one without requiring alteration of cylinder 102, and the second requiring a single radial hole into cylinder 102. An elongate, cylindrical plug 101 is axially inserted inside the cylindrical cavity 102d of cylinder 102. End plate 68 is recessed to receive face plate 72 of plug 101. Absent such components of the locking mechanism as cylindrical pins 101b and sidebar 101g, plug 101 should be sized to freely rotate around an axis B that is parallel to the longitudinal axis of cavity 102d. Plug 101 contains an axially elongated keyway passage 101a shown in the front, cross-sectional and rear views of Figures 10, 11 and 12, respectively, extending axially through exposed plate 72 of cylindrical plug 101. Keyway passage 101a is configured to accommodate reciprocal insertion of the blade of a key (not shown) that has been correctly profiled to conform to the profile of keyway 101a. Although not essential to the practice of all embodiments of the principles of this invention, plug 101 may also contain a mechanical locking mechanism such as a set of pin tumblers 101b. Pin tumblers 101b are biased into the bottom of corresponding pin chambers 101k by corresponding separate springs 101e restrained within the body of plug 101 by coverplate 101f' covering chambers 80, 82, and fitted snugly into an axially extending slot 101y adjacent to the exterior circumferential surface of plug 101.

Plug 101 also contains sidebar 101g tapered into an acute (frequently blunted), axially extending bearing edge 101h partially recessed into a beveled slot 102a formed axially along the

exterior circumferential surface of cylinder 102. Sidebar 101g is typically biased radially outwardly by one or more springs 101k so that the leading axially extending edge 101h of sidebar 101g protrudes into slot 102a of a cylinder 102 encasing plug 101 after the complete plug 101 has been installed into cylinder 102. Pins 101b are cut in this particular embodiment with a groove 101d, which may be made circular to accommodate rotation of pins 101b during insertion of a key. When the blade of a mechanical key that has been bitted to correctly displace pins 101b radially outwardly from keyway 101a within their corresponding chambers 82 is inserted with the cuts of the land of the key precisely matching the coding (axial separation between the upper and lower portions of pins 101b) of pins 101b, then slots 101d will align with the pegs 101m of the sidebar 102g. When rotational torque is manually applied to the key by the user, the beveled edges of slot 102a enables sidebar 101g to move radially inwardly toward plug 101 and away from groove 102a against the bias of springs 101k slightly, but enough to allow plug 101 to rotate within cylinder 102, thus concomitantly rotating tailpiece 101q which, in turn, rotates a movable cam 103 or other member engaged by tailpiece 101q.

The user may then rotate the key until plug 101 is aligned with a key extraction point where alignment between chambers 82 and the corresponding tumbler pins 101b allow the bias of springs 101k to force sidebar 101g radially outwardly until beveled edge 101k mates with slot 102a, and thus permits withdrawal of the key from keyway 101a. Two or more grooves, or slots 102a may be formed into the interior 102d, spaced arcuately apart to provide several arcuately separate points at which a key may be extracted from plug 101. When pins 101b are engaged in the properly manufactured corresponding cuts in the blade of the key and each of pins 101b is correspondingly

radially displaced outwardly within its chamber 82, and pins 101m of sidebar 101g engage corresponding circular grooves 101d formed in some, or all, of pins 101b as those pins 101b are forced radially outward by the bits of the key. The interengagement of pegs 101m and grooves 101d prevents radial movement of pins 101b and the concomitant release of the blade of the key within keyway 101a; the blade may only be extracted from keyway 101a when beveled edge 101h of sidebar 101g is correctly aligned with groove 102a.

A release assembly such as a reciprocating solenoid coil 105b driving blocking armature 105a resides coaxially within chamber 80. Coil 105b has a centrally located hole 105f for receiving shaft 105d when electrical current passes through coil 105b. Armature 105a forms the radially outward distal end of solenoid coil 105b, and is radially outwardly biased by spring 105D so as to place a circumferential surface 105k to engage, and block, a corresponding pin 101m of sidebar 101g. Release assembly 105 is electrically connected to electronic logic and control circuit 104b encapsulated within electrically insulated casing 104 formed to define an outer sector of cylindrical plug 101. Power, or power, protocol, identification and control data may be transmitted from a key inserted into keyway 101a via electrical conductor 104x, extending between an aperture 101n in the face plate 72 and the electrical conductor (*e.g.*, a local ground return) formed by the electrically conducting parts forming keyway, respectively, or alternatively via two or more pairs of apertures 101n and electrical conductors 104x, and corresponding input ports to circuit 104b. Electrical leads 104m, 104n, extend between a pair of output ports of circuit 104b and solenoid coil 105c of blocking armature 105a.

Solenoid 105b enables an existing plug to be retrofitted simply by substituting solenoid 105a

in chamber 80 for one of tumbler pins 101b and a concomitant re-bitting of the corresponding key to omit from the blade of the key any tooth corresponding to the cylinder occupied by solenoid 105b, with application of electrical power to solenoid coil 105b radially forcing armature 105a radially outwardly against the compressive force of spring 101e in order to align groove 105n with peg 101m. Alternatively, with a different location of groove 105n, solenoid 105b may be wound to draw blocking armature radially downwardly into cylinder 80, against the compressive force of a spring 105D (not shown) positioned between blocking armature 101a and coil 105b.

In a particular practice, the diameter of one of pin cylinders 80, 82 may not be sufficiently wide to accommodate a particular solenoid and will require reboring of the cylinder. The rebored plug can still be retrofitted into an already installed cylinder however, without the necessity of removing cylinder 102.

Turning again to Figures 13 and 17, an existing plug and cylinder may also be modified with the addition of an electromagnetic release assembly 109 to the exterior of cylinder 102, and by radially boring one or more aligned apertures 102w, 101w through cylinder 102 and into plug 101 to accommodate reciprocal passage of either one, or and array of blocking armatures 109a. Power for solenoid coils 109b may be supplied and switched by a source of electrical power external to the lock cylinder plug 102 via two or more electrical leads 109E and an external contact assembly 109F which attaches circumferentially around the outside of the cylinder shell 102 and custom multiple spring loaded pin armatures 109b passing through the apertures 102w bored into the wall of cylinder shell 102 and entering into the corresponding blind apertures 101w bored into plug 101 to prevent

rotation of plug 101 relative to cylinder shell 102 even after the blade of a correctly bitted key had precisely radially displaced the pin tumblers 101b. Installation of contact assembly is made by spreading clip wings 109H apart enough to allow them to pass around cylinder shell 102 to enable contact guide boss 109J to seat into through aperture 102w and enter aperture 101w, and wing male catch 109G' is firmly engages female catch 109G. The harness 109E is placed so as not to interfere with cam 103 and plug connector 109F may be connected to an external power supply and switching device that is local to the site of the lock, or is connected to a power and control bus to multiple locks.

Power may alternately supplied along with data through plug face contacts 104x which is connected to printed circuit 104b. Plug face contact 104x passes through face plate 72 from the cavity 101p to the outside exposed face of the plug via hole 101n. In this version data and optionally power may be supplied by the user held door key. A logic circuit with a microprocessor, communication, memory and switching means will be contained in casing 104 and its circuit 104b. When key means is presented and inserted in the lock and contacts on key means are in electrical contact with contacts 104, a process of authentication and comparison of encoded data occurs. An agreement of data, will result in the logic circuit switching power to coil 109b. In the event there is not an agreement of data then the lock remains in its normal state.

Turning now to Figure 18, power for the coils 105b, 106b, 107b or 108b may be supplied and switched by a source of electrical power such a battery 202 carried by a doorkey 200 external to the lock cylinder plug 101 via one or more external contact assemblies 104x, 104y as are manufactured

by a vendor such as Interconnect Devices, Inc. passing through external contact window 101n, with contact 104x attached to printed circuit 104b. The circuit board 104b is housed or encapsulated in circuit housing assembly 104 and is electrically connected to coil windings 105b, 106b, 107b or 108b.

One hierarchy for a cylinder lock system is represented in Figure 19, using a standard, mechanically bitted key 210 in conjunction with electromechanical key 200. In this configuration, cylinder locks 211, 212 and 213 are stand-along locks of the type using release assemblies 105, 106, 107 or 108, that can be opened and closed with electromechanical key 200. Cylinder locks 214, 215 are electrically coupled to a host data and power bus and may be opened and closed with either key 200 or with mechanical key 210, albeit the centrally located controller 220 controls, and overrides where desired, access through locks 214, 215 via power and data bus 222. Cylinder locks 106, 107 are stand-alone mechanical locks and may be accessed by either the correct mechanical bitting of electromechanical key 200 or of mechanical key 210.

Figure 20 illustrates a second hierarchy of a cylinder lock system in which electromechanical key 200 providing its own electrical power is able to mechanically and electrically unlock and lock stand-alone electromechanical locks 211, 212, 213 of the types using release mechanisms 105, 106, 107, 108, while a different electromechanical key 209 is able to unlock and lock cylinder locks 214, 215 controlled by a central controller 220 via a host power and data bus 222.

With the configuration illustrated in Figure 21, electromechanical key 200 is able to unlock and lock all of cylinders 211, 212, 213, 214, 215, 216 and 217, and to set cylinder 213 into a bypassed state to enable mechanical key 209 to unlock and lock cylinder 213.

In the configuration illustrated in Figure 22, stand-alone locks 211, 212, 213 using a bypassable release mechanism such as 108, may be set into a bypassed position by key 200 to allow a simple mechanically precisely bitted mechanical key 210 to unlock and lock these cylinders, while either the same key 200 or alternatively host controller 220, is able to set locks 214, 215 into a condition enabling key 210 to unlock and lock those cylinders. Mechanical locks 216, 217 may be independently accessed by key 210.

The foregoing details describe an electromechanical locking system using a plug constructed with a first base bearing a keyway providing a first electrical conductor and an orifice spaced-apart from and separated by a mass of the plug from said keyway; a second base separated by an axial length of the plug from said first base, said second base bearing a tailpiece for supporting a cam; an exterior surface extending between and engaging the first base and the second base; a locking mechanism responsive to a key inserted into said keyway to accommodate rotation of the plug relative to a cylinder surrounding the plug when the key while inserted into the keyway engages in a selected relation with the locking mechanism and engaging the cylinder absent the selected relation; a second electrical conductor terminating with an electrical contact exposed to an exterior of the first base through the aperture; an electronic logic circuit coupled to receive electrical power and data signals via the first and second electrical conductors, and generating control signals in dependence upon the electrical power and data signals; and an electrical operator having a distal member travelling in dependence upon the control signals between a first position relative to the exterior surface enabling rotation of the plug in relation to a cylinder surrounding the plug and a second and

different position relative to the exterior surface obstructing the rotation of the plug in relation the cylinder.

The plug of this system is constructed with the locking mechanism, logic circuit and electrical operator simultaneously experiencing the rotation relative to the cylinder whenever the plug rotates relative to the cylinder. The plug is constructed with the locking mechanism, logic circuit and electrical operator being wholly within the cylinder and travelling with the plug whenever the plug moves relative to the cylinder. The plug is configured with the electrical operator maintaining the distal member within the plug with the distal member extended not beyond the exterior surface while the distal member is in the first position, and maintaining the distal member in engagement with the cylinder while the distal member is in the second position. The electrical operator maintains the distal member within the plug with the distal member extending not beyond the exterior surface while the distal member is in the first position, and moves the distal member radially between the first position inside the exterior surface and the second position radially beyond the exterior surface, in dependence upon the control signals.

Alternative construction of these features is possible without departing from the principles of the present invention. For example, the plug used in Figure 1 to illustrate the foregoing principles is described as having a tailstock configured to support a cam. In some configurations, the plug may be configured to drive either a locking mechanism or an electrical switch.